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A COMPARISON OF 'PULSE-STRETCH' AND CONVENTIONAL MARKING TECHNI--ETC(U)
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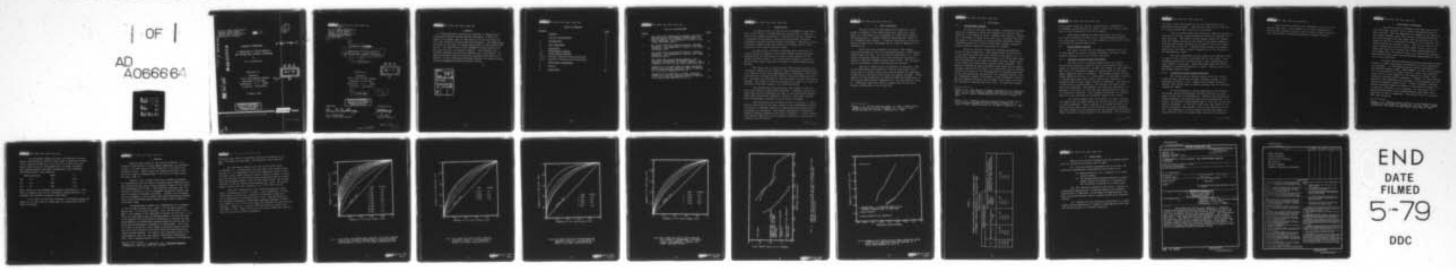

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TECHNICAL MEMORANDUM

A COMPARISON OF "PULSE-STRETCH" AND CONVENTIONAL MARKING TECHNIQUES

by

M. B. Montgomery

Submitted to

Commander
Naval Ship Systems Command
Department of the Navy
Washington, D. C. 20360
Attention: Code PMS-87

12 March 1968

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6500 Tracor Lane, Austin, Texas 78721, AC 512/926-2800

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ABSTRACT

Psychophysical methods were employed in comparing proposed pulse-stretch display marking techniques, in which the length of a display mark is some function of the processor output, with intensity (Z-axis) modulated displays. The comparisons were made on the basis of signal detectability using observer ROC curves. The simulation of these AN/SQS-26 A-scan displays was done with the aid of a digital computer. Both constant and variable intensity pulse-stretch marking were investigated. The matched display using only intensity modulation was found to be superior to those using pulse-stretch marking for signal-to-noise ratios encompassing minimum detectable levels.

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1. INTRODUCTION

To enhance fleet utilization of the AN/SQS-26 sonar equipment in the field of display-observer interactions, a study was made of the comparative ability of observers to detect signals on a simulated A-scan display using both conventional (intensity modulated) and pulse-stretch marking techniques. Basically, pulse-stretching requires that the length of a display mark be some function of the signal processor output.

In this study, baseline performance was established for several values of signal-to-noise ratio (S/N) using conventional marking where the intensity of a mark is some function of the signal processor output. The conventional display is matched to the processor output data rate by means of a multichannel serial OR gate.

The first type of pulse-stretch (PS) marking studied uses a constant intensity; the length of each independent displayed mark is a function of its input magnitude above a threshold. The second pulse-stretch technique (PS+I) combines intensity modulation with PS. Intensity is controlled in the same manner as with conventional marking. The effect is that the intensity of a mark is an implicit function of the mark length of the stretched pulse.

The investigation described here was limited to the six echo cycle history, single beam situation. Although it would seem that pulse-stretch techniques use more of the limited CRT dynamic range than conventional displays, results of this study indicate that no advantage is gained by use of these techniques.

Test procedures are discussed briefly in Section 2, along with an indication of the error bounds on the experimental results. In Section 3, technical aspects of conventional and pulse-stretch techniques are discussed. Preliminary experiments to determine suitable display parameters are noted in Section 4. Actual results from observer ROC curves are presented in Section 5, and Section 6 contains the conclusions.

2. TEST PROCEDURES

Several series of film-strips were presented to four groups of subjects, each group having four observers. Each frame of a film-strip is a photograph of a CRT which displays data generated by a digital computer simulating the output of the AN/SQS-26 sonar system. A complete description of the processes involved in the simulation may be found in Appendix A of reference (1).

Each film-strip contained 150 frames, with signals occurring randomly at one of six positions within a frame approximately half the time. For the control conditions, i.e., those using conventional marking, nine film-strips were generated, each at a different signal-to-noise ratio (S/N). For the pulse-stretch techniques, twelve film-strips were produced.

Data were obtained from the subjects in two ways. Each of the film-strips was viewed six times by each group, three times using a 4-point rating scale scoring method for generation of ROC curves, and three times using the regular scoring[1]. Determination of the probability of detection P(D) and probability of false alarm P(FA) allowed computation of the detectability index d'. Sufficient data were taken to ensure that the $\pm 1\sigma$ error bounds on P(D) would be less than 0.05.

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[1] Young, J. M., "Final Technical Report on Task 5, NObsr-95149, AN/SQS-26 Display Analysis," TRACOR, Inc., Austin, Texas, TRACOR Document No. 66-704-U, September 30, 1966.

3. DISCUSSION

3.1 CONVENTIONAL MARKING

As used in this and other studies, conventional marking refers to a display on which the intensity of a mark is some function of the amount by which a sample value exceeds a threshold. The number of marks in an echo cycle, and hence the marking density, is controlled by adjusting the threshold setting. A marking density of 1.0 can be used with variable intensity marking without completely saturating the display.

There are various methods for choosing quantization levels for the intensities. The method chosen for this study is one which has given the best results in the past[2], i.e., a conventional display with marking density of 1.0 and with intensity proportional to the amount by which selected sample values at the signal processor output exceed a lower threshold. All samples exceeding an upper threshold cause marks at the highest intensity which will not "halo", or occupy more than one display location (criteria for the determination of threshold settings, in dB, have previously been given[3]). In a matched display, only one independent sample is allocated to each resolvable location. For the simulated display used in these tests, there were some 200 resolvable locations per echo cycle. To match the display

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[2] Young, J. M., "The Effect on Signal Detectability of Using Four, Five, Six or Seven Discrete Marking Intensity Levels," TRACOR, Inc., Austin, Texas, TRACOR Document No. 67-649-U, August 16, 1967.

[3] Young, J. M., "Receiver Operating Characteristic (ROC) Curves for a Simulated AN/SQS-26 A-Scan Display," TRACOR, Inc., Austin, Texas, TRACOR Document No. 67-1088-U, January 10, 1968.

to the signal processor output, a matching box, consisting of a 24-channel serial OR gate was used to select the largest sample value in each sequential block of 24 samples.

Conventional marking, as described above, was used as the control condition in this study. Pulse-stretching methods, to be discussed in Section 3.2, are compared to the control condition mainly by observer ROC curves.

3.2 PULSE-STRETCH MARKING

Two types of pulse-stretch marking techniques were used in this study, one using a constant intensity, the other using variable intensity as in the control condition.

3.2.1 Constant Intensity Pulse-Stretching

The first type of marking compared with the control (conventional marking) condition uses a pulse-stretch (PS) technique, at constant intensity, in which the length of each displayed spot due to an independent sample is proportional to the input sample magnitude above a threshold. The maximum allowed stretch length (MASL) is limited to a fixed number of resolvable locations. A constant amplitude pulse, which controls the intensity, is generated when an input sample exceeds a threshold. The duration of this pulse is proportional to the matching box power output above the threshold. (For samples just above the threshold, the duration of the pulse is such that the displayed mark occupies one resolvable location). The elongation (stretch) of a display mark is in the direction of increasing range on the A-scan.

If a given display mark is stretched, no other independent samples may be marked during the stretch interval regardless of their magnitudes. Thus, inherent in the pulse-stretch technique used in these tests is the rejection of certain independent data samples from the matching box (24-channel serial OR gate). (This rejection of data samples is not mandatory. The simulation

was done in this way because it is less restrictive on the available marking density. This will be made clear in Section 4, in which preliminary results are discussed).

Since one data sample may occupy more than one resolution interval on the CRT, pulse-stretching violates the matched display criterion. The number of data samples which are blanked from the display depends on the number of preceding samples in each ping which have exceeded the threshold, and on the amount by which they exceed it. Localized noise sources can produce marks which can blank a signal irrespective of its strength at the matching box output.

The time represented by each sample at the OR gate output is equal to the inverse of the data rate at this point. Over-averaging effects are introduced when a spot representing an input sample is stretched. Pulse-stretching also has effects analogous to defocusing parallel to sweep. However, more of the CRT dynamic range is used.

3.2.2 Variable Intensity Pulse-Stretching

The second type of marking compared with the control condition was a pulse-stretch (PS) technique similar to that described in Section 3.2.1. Rather than constant intensity, however, this second type of marking combines PS with intensity modulation, (PS+I).

In the simulation, a device operating on the matching box output (after thresholding) initially produces an output equal to that from the matching box. Whenever the matching box output decreases, its previous peak level is maintained by the device, the duration being proportional to the level of the peak above a threshold. At the end of this time, the output of the device decreases to the present level of the matching box output. The duration of a given output controls the length of a pulse-stretch, while the output power controls the intensity.

With the above addition, all statements of the previous section apply here. The contrast to the noise background resulting from variable intensity should improve signal detectability with respect to pulse-stretching at constant intensity.

4. PRELIMINARY EXPERIMENTS

The pulse-stretch techniques could have been altered such that data rejection (due to pulse-stretching) would not have occurred. When the magnitude of a sample at the matching box output reached a peak level during a stretching interval, and this new peak level was higher than the previous one, the output of the device mentioned in Section 3.2.2 could have been made to assume the new peak output. This was not done in the tests reported here since it would result in more severe mismatch, and would also increase the actual marking density on the display above the desired value, with deleterious effects[4]. These effects were noted from preliminary experimentation, which will now be described.

To attain optimum detectability when using pulse-stretch methods, certain compromises as revealed by initial experiments are necessary. As the marking density (before stretching) or the maximum allowed stretch length (MASL), or both, are increased, so is the probability of data rejection. Here, data rejection refers only to those samples at the matching box output which exceed the marking density threshold. Further, for lower marking densities, the threshold must be higher, thus increasing the MDL (minimum detectable signal level). Proper coupling of marking density and MASL depends on whether a pulse-stretch display is to be used for detection or for tracking. For the latter use, a lower marking density with correspondingly higher MASL could generally be used to advantage. The present study is concerned only with detection.

[4]Young, J. M., "Marking Density Studies for the AN/SQS-26 Sonar Equipment A-Scan Display," TRACOR, Inc., Austin, Texas, TRACOR Document No. 66-316-U, Contract NObsr-95149, May 20, 1966.

In preliminary (Phase I) tests, 16 observers were presented film-strips for each of three types of pulse-stretching, all at constant intensity, at an S/N of 11.7 dB at the processor output, and at a 50% probability of signal incidence. With marking density and MASL as parameters, the following detectabilities d' were observed:

	Marking Density	MASL	d'
(a)	0.1	5%	0.88
(b)	0.2	2½%	0.74
(c)	0.1	2½%	1.15

Thus, condition (c) provided the greatest detectability. From this, it appears that for PS techniques, marking density is a somewhat more sensitive parameter than MASL.

As a result of the above findings, the display parameters listed in (c) were used in comparisons of conventional and PS types of marking.

5. RESULTS

Observer ROC curves for the control condition, i.e., intensity proportional to input sample magnitude, are presented in Fig. 1 for nine values of S/N, from 9.6 to 12.0 dB at the processor output. These curves are compared with ROC curves for the PS type of marking (Figs. 2-3) as well as with curves for PS+I, (Fig. 4).

Figures 2 and 4 reveal that only a slight improvement in detectability over PS alone is obtained upon combining intensity modulation with pulse-stretch marking (except at the lowest S/N investigated (10.7 dB)). This behavior indicates that the observer's function is one of alignment recognition rather than one of relying on intensity contrasts. However, the determination of alignment is more complex than with conventional marking since pulse-stretching causes unequal signal pulse lengths in successive pings.

The geometrical length of a "signal" pulse as it appears on the A-scope is given by $s\tau$, where s is the sweep speed in mm/sec and τ is the pulse duration. Let ℓ be the ratio of the MASL to the length of one resolvable location (in our case $\ell = 5$). Then, for some given value of marking density, the S/N increase in dB required for pulse-stretch techniques to furnish the same detectability as conventional marking should be of the order of $\sqrt{\ell}$ if pulse-stretching is analogous to defocusing[5]. This relation will be valid for a wide range of processor output S/N values, and is an extension of results found for deflection modulated A-scope displays. The square root dependence seems to be approximately valid for the range of S/N values investigated here, with a marking density of 0.1. (Preliminary investigations

[5] Lawson, J.L., and G. E. Uhlenbeck, eds., Threshold Signals, McGraw-Hill, New York, 1950, pp. 211-216.

indicated that, should the marking density be increased to 0.2 while retaining the same MASL, the dependence would approach $\sqrt{2\ell}$.)

The S/N values required for each of the three types of marking, i.e., conventional, PS, and PS+I, for a given detectability, d', are obtainable from direct comparison of the respective ROC curves. These values of S/N are listed in Table I, along with the increase in S/N required when using pulse-stretch rather than conventional marking. For the S/N range listed, the average increase in S/N for pulse-stretch marking is 2.5 dB. This value agrees closely with that predicted, i.e., $\sqrt{\ell} = \sqrt{5} = 2.24$ dB.

Two other indications of the relations among the three types of marking are noted. In Fig. 5, the probability of false alarm P(FA) is plotted as a function of processor output S/N for a probability of detection P(D) = 0.50. The superiority of the intensity modulated, conventional marking technique is obvious; P(FA) is 0.17 to 0.23 less than that afforded by pulse-stretch displays. Figure 6 is a plot of P(D) vs processor output S/N, for P(FA) = 0.10. P(D) is 0.23 to 0.36 greater than that obtained with the two pulse-stretch techniques.

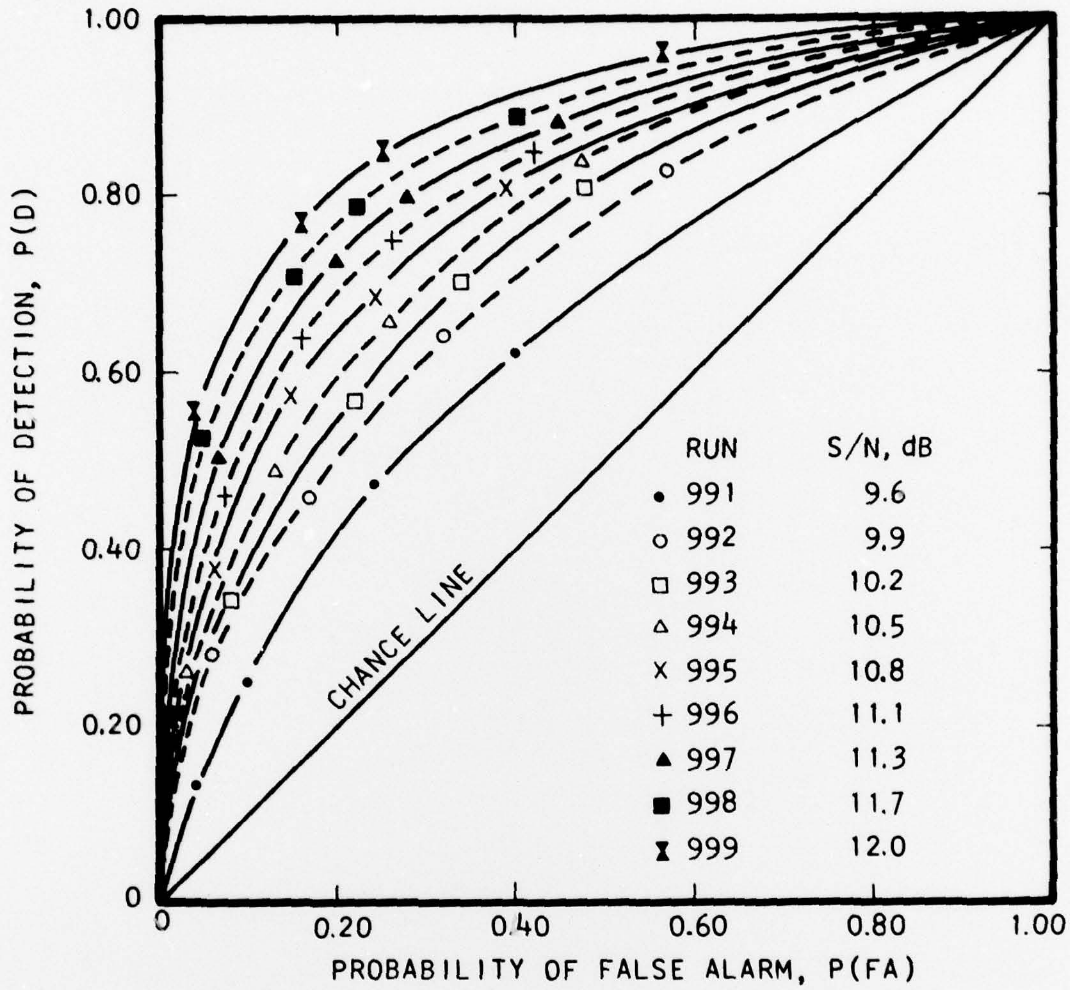

FIG. 1 - ROC CURVES FOR CONVENTIONAL MARKING, WITH UNITY MARKING DENSITY AND INTENSITY PROPORTIONAL TO INPUT MAGNITUDE. THE PARAMETER IS (S/N) AT THE SIGNAL PROCESSOR OUTPUT.

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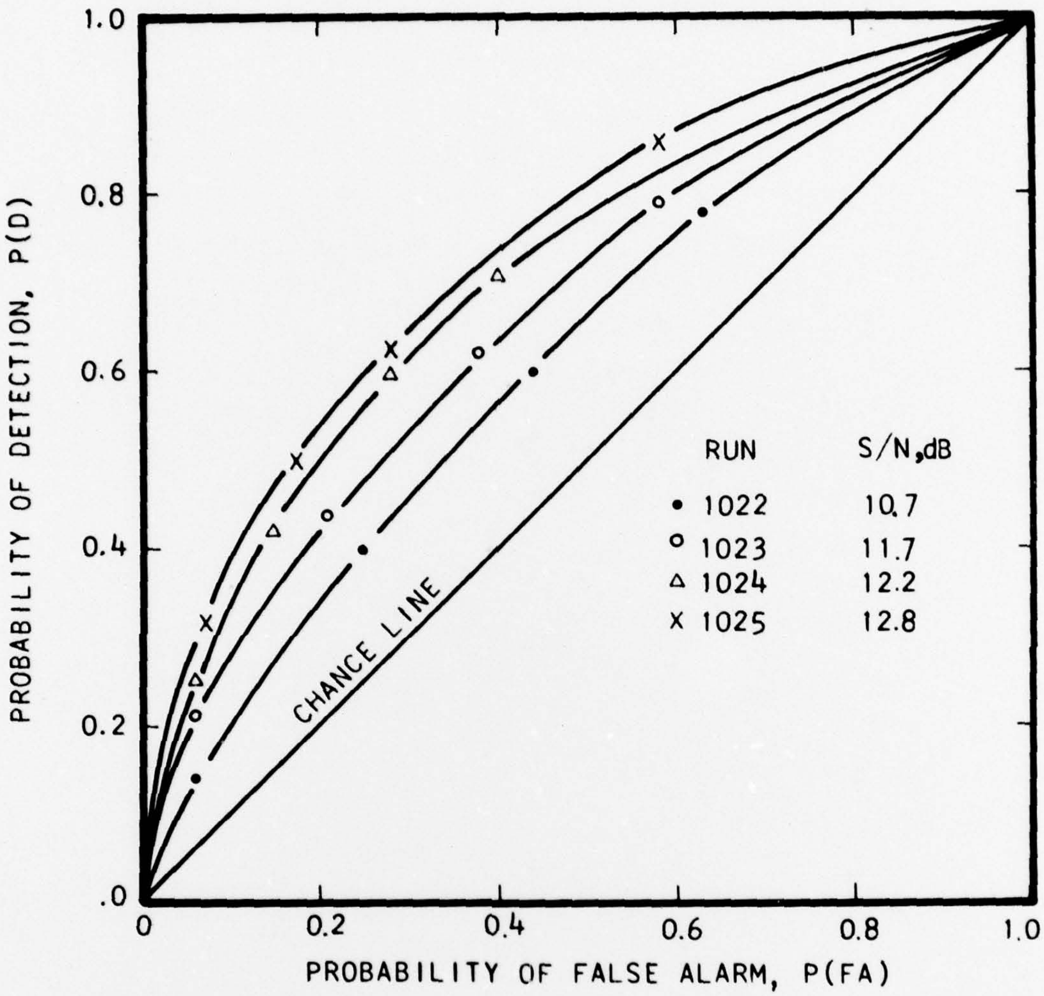

FIG.2 - ROC CURVES FOR PULSE-STRETCH MARKING, CONSTANT INTENSITY. THE PARAMETER IS (S/N) AT THE SIGNAL PROCESSOR OUTPUT.

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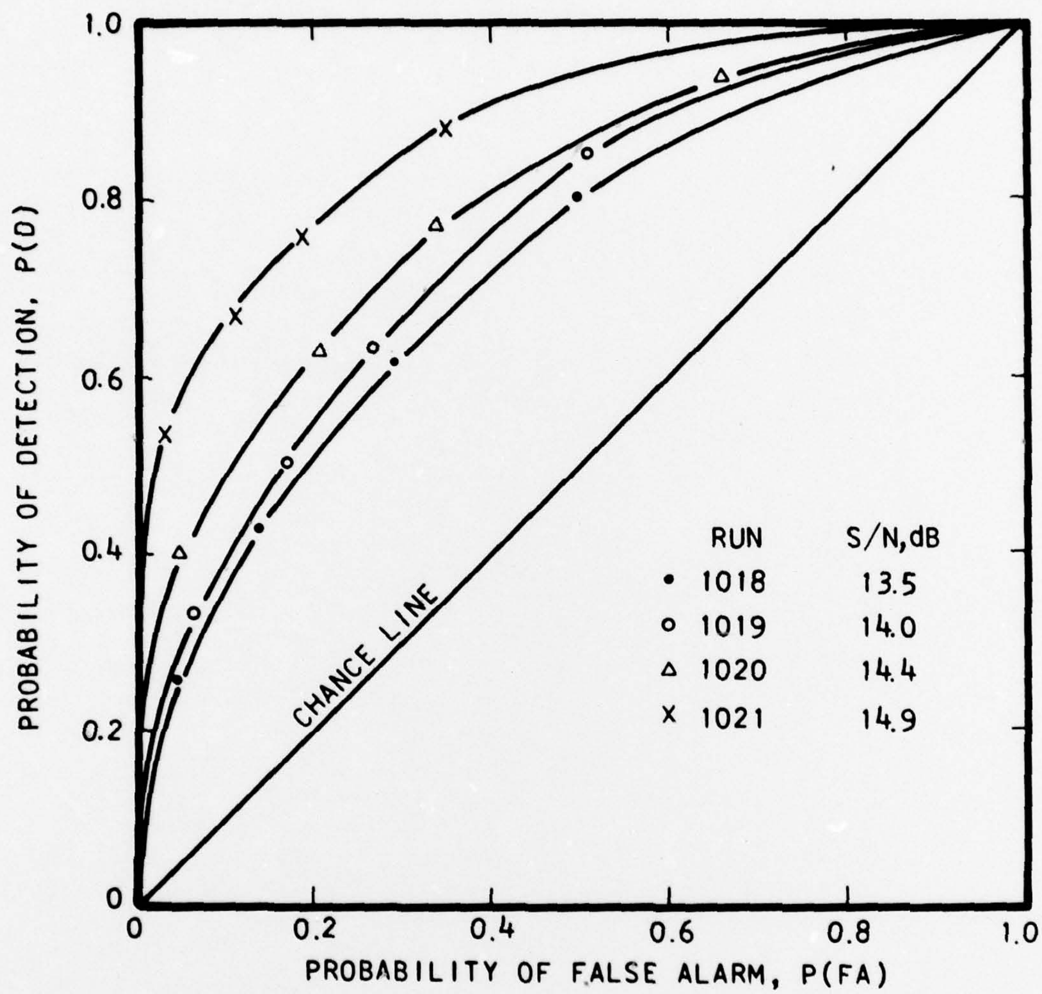

FIG.3 - ROC CURVES FOR PULSE-STRETCH MARKING, CONSTANT INTENSITY. THE PARAMETER IS (S/N) AT THE SIGNAL PROCESSOR OUTPUT.

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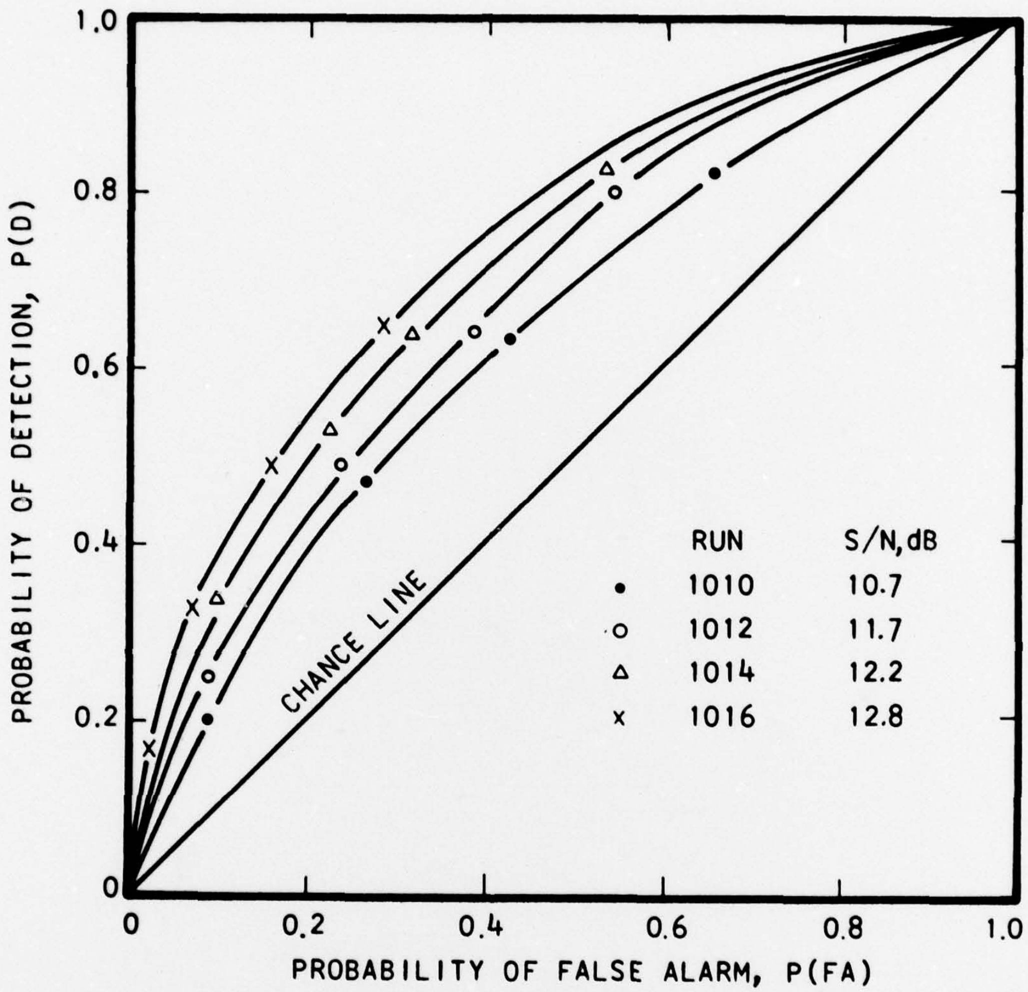

FIG.4- ROC CURVES FOR PULSE-STRETCH MARKING, WITH INTENSITY PROPORTIONAL TO STRETCH LENGTH. THE PARAMETER IS (S/N) AT THE SIGNAL PROCESSOR OUTPUT.

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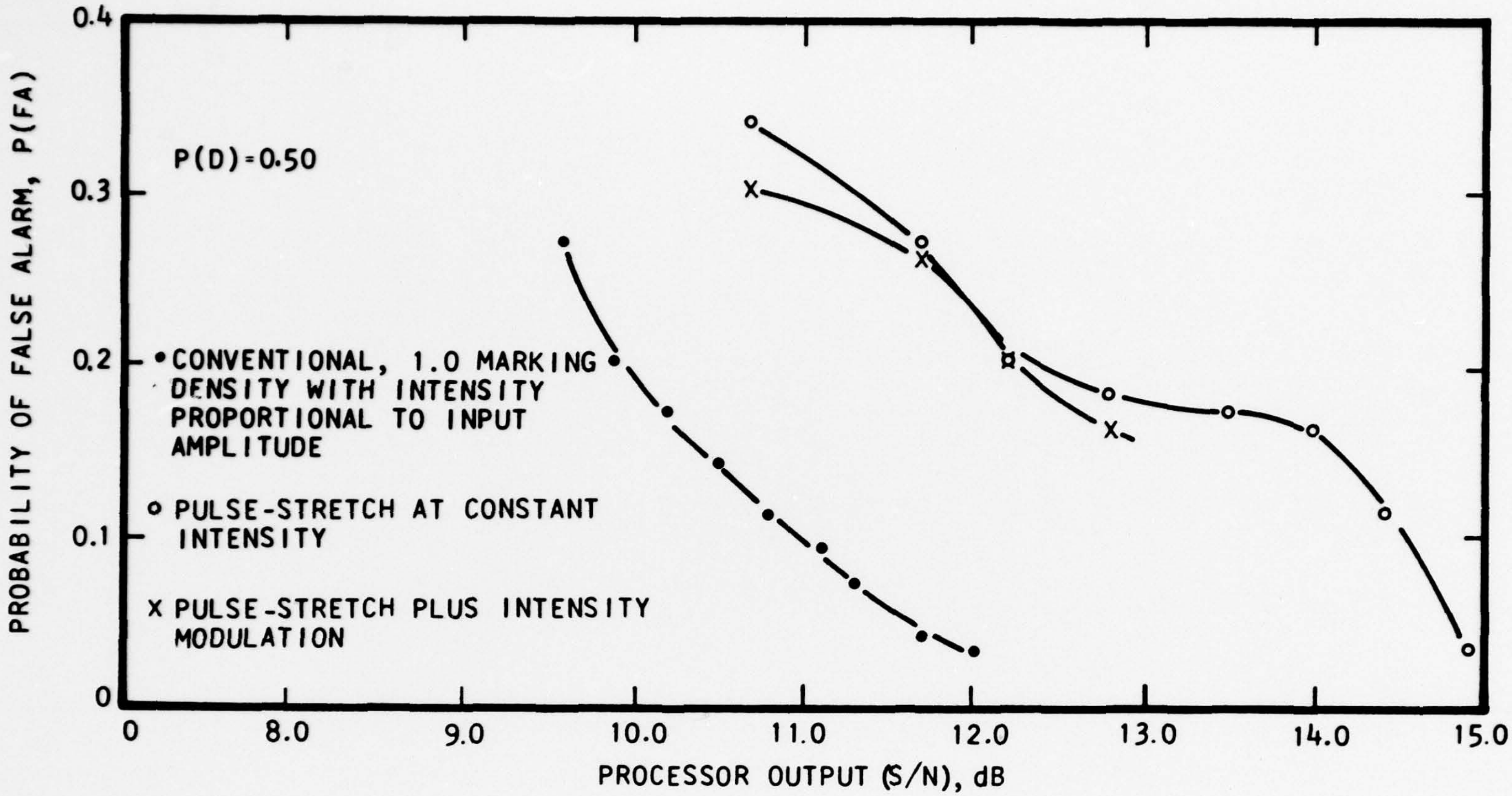

FIG. 5 - PROBABILITY OF FALSE ALARM VS SIGNAL PROCESSOR OUTPUT (S/N) FOR THE INDICATED TYPES OF MARKING, AT A DETECTION PROBABILITY OF 0.50.

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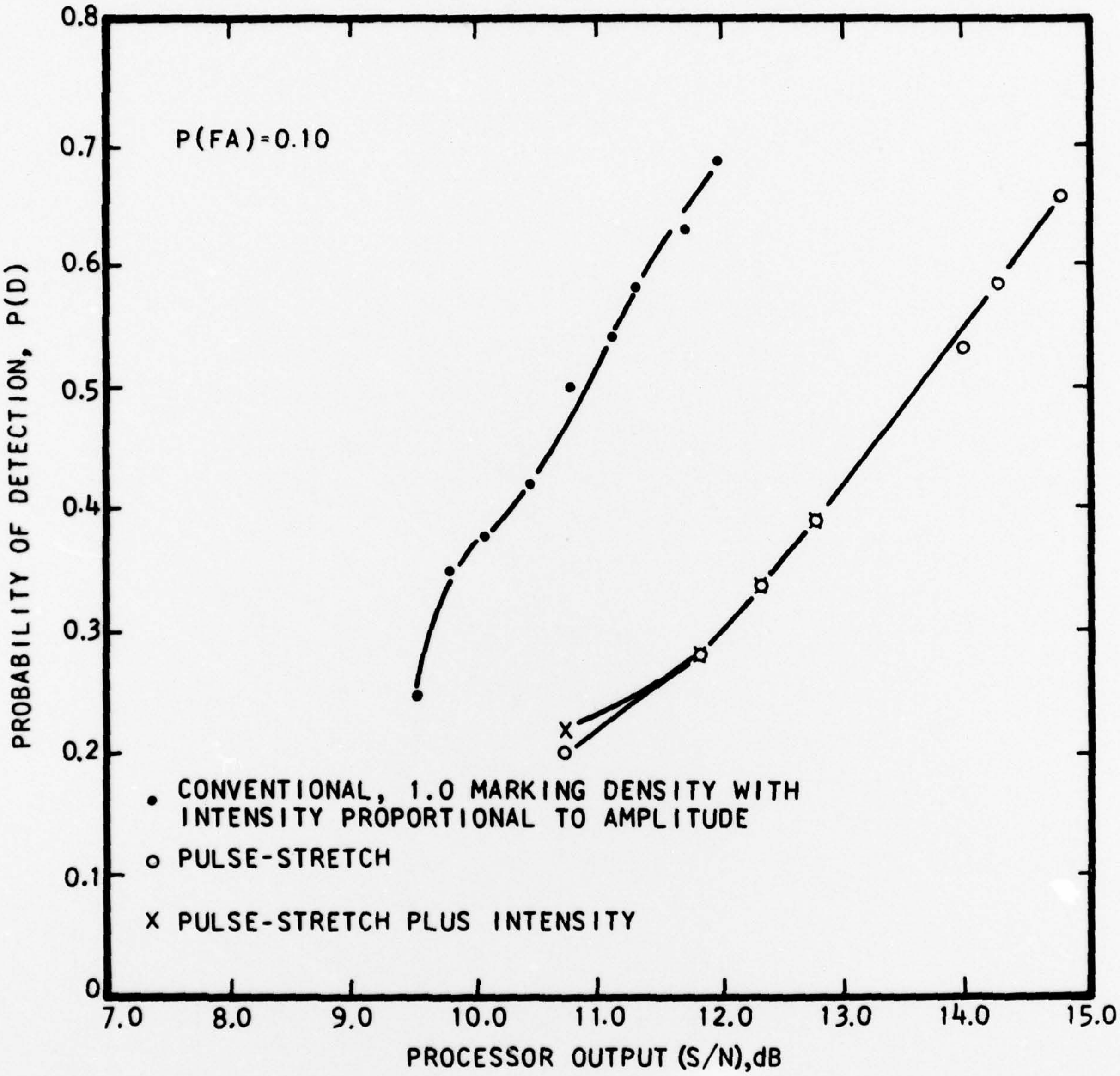

FIG. 6– PROBABILITY OF DETECTION VS SIGNAL PROCESSOR OUTPUT (S/N) FOR THE INDICATED TYPES OF MARKING, AT A FALSE ALARM PROBABILITY OF 0.10.

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TABLE I

SIGNAL-TO-NOISE RATIO REQUIRED AT THE PROCESSOR OUTPUT TO FURNISH A GIVEN DETECTABILITY d' FOR EACH OF THREE TYPES OF MARKING

SIGNAL-TO-NOISE RATIO				
d'	Conventional	Pulse-Stretch (PS)	Pulse-Stretch Plus Intensity (PS+I)	Differential in S/N between Pulse-Stretch and Conventional Displays for Equal Detectability
1.08	9.6 dB	11.7 dB	11.7 dB	2.1 dB
1.41	9.9	12.2	12.2	2.3
1.60	10.2	12.8	12.8	2.6
2.40	12.0	14.9	----	2.9

6. CONCLUSIONS

Based on the results obtained from this display experiment the following conclusions can be drawn.

(1) If pulse-stretch techniques are to be used, the conditions yielding best detectability were found to be:

a) Marking density = 0.1, referred to a conventional display.

b) The maximum allowed pulse-stretch of a given sample should be limited to 2.5 percent of the resolvable locations on a single ping.

(2) The effective signal-to-noise ratio, relative to conventional marking with 1.0 marking density and intensity proportional to magnitude, is decreased by approximately 2 dB when using pulse-stretch alone or pulse-stretch plus intensity marking.

(3) Marking with an intensity proportional to stretch length offers essentially no change in detectability from that with pulse-stretch at a constant intensity.

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13. ABSTRACT

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14 KEY WORDS	LINK A		LINK B		LINK C	
	ROLE	WT	ROLE	WT	ROLE	WT
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Display Marking						
Pulse-Stretch Methods						
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